PRACTICAL SILO CONSTRUCTION

A TREATISE

ILLUSTRATING AND EXPLAINING THE MOST SIMPLE AND EASIEST PRACTICAL METHODS OF CONSTRUCTING CONCRETE SILOS OF ALL TYPES; WITH UNPATENTED FORMS AND MOLDS. THE DATA, INFORMATION AND WORKING DRAWINGS GIVEN IN THIS BOOK WILL ENABLE THE CONCRETE BUILDER TO SUCCESSFULLY CONSTRUCT ANY OF THE MOST PRACTICAL TYPES OF CONCRETE SILOS IN USE TODAY.

By

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TWENTY ILLUSTRATIONS

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FOREWORD

It is the purpose of the writer to present in this series of books a complete explanation of various successful methods of concrete construction that may be employed by the beginner as well as by the more experienced worker. I shall endeavor to give the details of molds and ideas that are not covered by patents, such as may be easily and cheaply constructed; hence the reader is not compelled to purchase expensive patented molds before putting into practise the many successful types of concrete construction I have exhaustively described in this series. There is no practical value to the reader in explaining a patented system of construction, other than a few words on its merits, as the owners of same are always pleased to give this information; hence in going outside the beaten track of concrete authors and presenting ideas, systems, and molds that are practical, successful in operation, and, above all, easily and simply constructed, I trust that I have merited the sincere gratitude of all fellow workers in the concrete field who seek such information.

Yours very truly,

A. A. Houghton.

PREFACE

THE concrete silo has easily demonstrated its superiority over all other types of silo construction, and to-day stands, in the opinion of every practical builder, as the nearest to perfection of any type of structure for the preservation of green crops in silage. When we hark back to the civilization of the past centuries, we find that the silo is but another modern adaptation of ancient building construction, bringing more forcibly to our notice "that there is nothing new under the sun."

In this treatise I have endeavored to show the requirements of silo construction to insure success, and the best methods of complying with these requisites when concrete is the material for the structure. The importance of the foundation is fully treated, as the structure can be no stronger than the foundation upon which it rests, and it is far better to err on the safe side in construction of the foundation than to find it inadequate for the load it must carry. As the solid wall silo is the usual type erected at the present time in monolithic construction, I have presented one of the most practical and positively the most simple and easily constructed wood form that has been published up to the present time.

The fact that this wood-clamp silo form is rigid and amply strong for the work of a construction that requires the minimum of lumber, and is easily raised in a manner that makes it almost impossible to get the walls from a perfect vertical line, should be of vast interest to every contractor or silo builder.

The molding of monolithic silo walls, with a continuous air-chamber between same, is also fully treated; one by employing a simple and easily constructed automatic wall-clamp, and also by the well-known method of building the walls from blocks or units.

The construction of silos from concrete plaster or stucco is also explained, as well as the reinforcement of silos, with tables for the proper placing of this reinforcing material. The different types of silo doors, and two methods of making a concrete roof—plain and ornamental—for the silo, are explained in detail.

Believing that this volume will fill every need of the contractor for practical and easily understood instruction upon this subject, and that it will be of value to you, I am,

Very truly yours,

A. A. HOUGHTON.

February, 1911.

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PRACTICAL SILO CONSTRUCTION

THE concrete silo has within the past year demonstrated to the majority of builders its superiority over all other types of silo construction. Not only for the great durability of properly made concrete does it base its claims for consideration, but in the fact that it can be made water-proof and frost-proof, as well as being absolutely air-tight, has done much to advance the concrete silo in the favorable opinion of the farmer as well as the builder. In the process of ensilage we are only adapting to our present day needs a method of preserving grains and green crops that has been in successful use for centuries. The fact that the masonry silos or granaries of the ancient Egyptians were built on practically the same plan as our present-day silos, and that this method of ensilage was in successful use for centuries, will be of interest to the doubter who believes that stone, either natural or artificial, is not the best material for the construction of a structure for the preservation of grain or any crop. In fact, the greatest enemy of the concrete silo to-day is the man who

has a silo to sell of some other material. The unanimous verdict of those who have built of concrete is that it has given the greatest satisfaction, with practically no future expense for painting and repairs, which is a large item with the wood and metal silo. Adding to this the fact that a properly constructed concrete silo is everlasting, we have a balance in favor of concrete that no other building material can hope to overcome.

The word silo is used to designate a closed pit or reservoir, in which green fodder or dry grain may be placed for preservation. Ensilage is the process of preserving the grain or green fodder in the pit or silo. Silage is the preserved fodder or grain, or the results produced by the process of ensilage. In present-day use the silo is employed for green crops almost exclusively, and upon our dairy farms of this country green corn is usually the material for our silage; in other countries, clover and other grasses, tares, rye, and oats, are used to produce silage.

REQUIREMENTS OF A SILO

The requisites of a successful silo are, first, its air-tight features. This can be accomplished for the first year or so in the lighter and less durable methods of construction; but, after the first few years of use, the seams or joints of the wood silo will spread apart and thus admit air. This demands repairs; and, in the years of use, it is easily to be seen that the slight extra cost of a concrete silo is saved many

times over in the upkeep or repairs necessary to the wood or metal silo.

These arguments, which are understood by those who have had the experience, apply also to the other features of a successful silo—durability, and a small repair bill.

The silo is best when water-proof and frost-proof. The penetration of moisture through the silo is very apt to injure the silage, as the preservation of the moisture is necessary to the process, while the freezing of the silage is very annoying when feeding it out, as large masses of it will adhere, by freezing, to the wall of the silo, and cannot be removed until thawed out. This does not injure the silage, but is an annoyance when feeding the silage, in the winter months.

The water-proofing of the silo can be easily accomplished by using any of the water-proofing compounds on the market, or by making the concrete in the walls as dense as possible. By using a wet mixture of concrete, the mortar will the more tightly pack together, thus reducing the size of the pores for the admittance of moisture to the silage, as well as preventing the moisture in the green fodder from escaping through the walls. Again, by the use of a brush, coat over the completed walls, of ordinary Portland cement, one part; hydrated lime, one-half part; this is mixed with water to the consistency of paint and applied with a wide brush to the walls as soon as forms are removed, and aids materially in

water-proofing the silo. In ordinary practise two or three thin coats of this material applied over the walls will be ample water-proofing for the purpose, as this brush coat fills the pores of the concrete in an effective manner. Caution must be observed in using this brush coat, that it is not applied too thick, as then it will craze or check, thus supplying cracks for the admission of moisture. By having it quite thin, and brushing well when spreading, the purpose is accomplished with two coats, successfully filling the pores but not applying more material than will perfectly bond with the concrete in the wall.

The thickness of wall does not prevent the freezing of the silage, for concrete, as with stone masonry, is not frost-proof in any ordinary thickness as employed for walls. The most successful method to avoid freezing of the silage is to build double walls to the silo, with an air-chamber between same. This is accomplished in the block construction and also in the monolithic type of construction. While freezing is not an injury to the silage, the protection of a double wall against same is a positive preventative against this annoyance in feeding—a feature that is of value in our cold winters of the Northern States.

The double wall silo with sealed air-chambers is also an assurance against the danger of air reaching the silage, as well as moisture penetrating the walls.

SIZE OF SILO TO ERECT

The diameter of the silo should not be larger than will enable the silage to be fed from the entire top each day. If the top is not fed out every twenty-four hours the silage is apt to mold; so, in construction, the number of animals to be fed from same should be the greatest consideration in planning the size.

A cubic foot of silage will vary in weight from 35 to 50 pounds. In estimating, 40 pounds to the cubic foot may be taken as the weight, with safety, in approximately determining the storage capacity of the silo.

The amount fed to a cow each day varies from 40 to 60 pounds, when used with other feed; hence, by employing a safe average of 50 pounds daily for each animal, it is possible to estimate the best size of silo to erect for the purpose, as each animal at this rate would consume three-quarters of a ton in each thirty days. It is always better to err slightly on over-capacity than otherwise, as the settling of the silage that takes place after filling will vary with the condition of the fodder at the time of filling; so this cannot be positively estimated. This is, of course, only in reference to the height of the silo, as the layer that is to be removed each day in feeding, to prevent molding of the ensilage, can be accurately determined so as to consume a layer of two or three inches in depth daily.

The following table will enable the size of the silo to be quite accurately estimated as to height when the diameter has been determined. Thus, by multiplying the capacity per foot of height by the proposed height of silo, you easily secure the approximate capacity in tons.

TABLE I

SIZE OF SILOS

6′	diameter	contains	$\frac{3}{4}$	ton to each foot of height.
8′	"	"	1	" " " " " "
10′	"	"	$1\frac{1}{2}$	tons to each foot of height.
12′	"	"	$2\frac{1}{4}$	" " " " " "
14′	"	"	3	" " " " " "
15′	"	"	$3\frac{1}{2}$	" " " " " "
16′	"	"	4	" " " " " "
18′	"	"	$5\frac{1}{10}$	" " " " " "
20′	"	"	$6\frac{1}{4}$	" " " " " "
25′	"	"	$9\frac{3}{4}$	" " " " " "

The usual practise is not to make the inside diameter of the silo greater than one-half the height, consequently a diameter of more than 20′ inside is not often required; where larger quantities are needed the best practise is to build several silos of smaller diameter and capacity, thus exposing as little of the silage to the air between feeds as possible.

By the table given it will be seen that, to furnish the silage ration for a herd of 10 cows—the lowest number that it is practical to build a silo for—they will consume about one-fourth of a ton daily, or 45 tons in 180 days, 60 tons in 240 days. This would require a silo 10′ in diameter and 33′ in height for 6 months' feeding, allowing 3′ for the settling of

the silage, which cannot be accurately estimated, as heretofore explained. In a silo 12′ in diameter the height for 6 months' feeding would be 23′, with the same allowance for settling. For 8 months' feeding the height of a 12′ silo would be 30′, on the above basis. As the 10′ diameter would permit the feeding of 500 pounds daily to remove a 2″ layer of silage, while the 12′ diameter would remove approximately about $\frac{3}{4}$″, it will be seen that the 10′ diameter would be the most practical from an economical point of view.

LOCATION OF SILO

The location of the silo should be such that it permits easy feeding, and when possible to place upon the south of the barns there is always less annoyance in removing the silage in bad weather, when it is constructed separate from the barn; also the animals may then be often fed in racks in the yard with less labor in placing the silage before them.

Where the floor of silo is placed too far below ground-level it is found to be more annoyance in removing the last few feet of silage; hence the floor-level should not be more than 4′ below ground-level to insure an easy removal of the contents. The matter of drainage is not needful to consider, as the material placed in the silo has a large percentage of water, which the silo must retain to prevent the silage from "dry firing"; so the foundation should be made as water-proof as possible, which will

also keep out the surface water as well as retain the moisture in the silage.

FOUNDATIONS FOR THE SILO

These must be given careful attention, as the life of the structure depends upon same. The practise of constructing the foundation in a haphazard manner is to be regretted; for, when we consider the weight of the concrete structure, as well as the weight of the column of silage it contains, the vast importance of amply protecting this in constructing an adequate foundation is easily to be seen.

At Fig. 1 is shown the usual type of foundation for a concrete silo, where the floor of same is at ground-level, as indicated at *a*. The dotted lines at *b* show the form of constructing footings, which are determined by the size of silo.

The following table will aid in determining the diameter and size of the footing courses for the different sizes of silos usually constructed.

TABLE II

DIAMETER AND SIZE OF FOOTING COURSES

Diameter of Silo in Feet.	For Stone, Clay, or Gravel.				For Sand or Loam Soil.			
	A.	B.	C.	D.	A.	B.	C.	D.
10′............	12′ 6″	2′	1′	12″	13′ 6″	3′	18″	12″
12′............	14′ 6″	2′	1′	12″	15′ 6″	3′	18″	12″
14′............	16′ 6″	2′	1′	13″	17′ 6″	3′	18″	13″
15′............	17′ 6″	2′	1′	13″	18′ 6″	3′	18″	13″
16′............	18′ 6″	2′	1′	14″	19′ 6″	3′	18″	14″
18′............	20′ 6″	2′	1′	15″	21′ 6″	3′	18″	15″
20′............	22′ 6″	2′	1′	16″	23′ 6″	3′	18″	16″

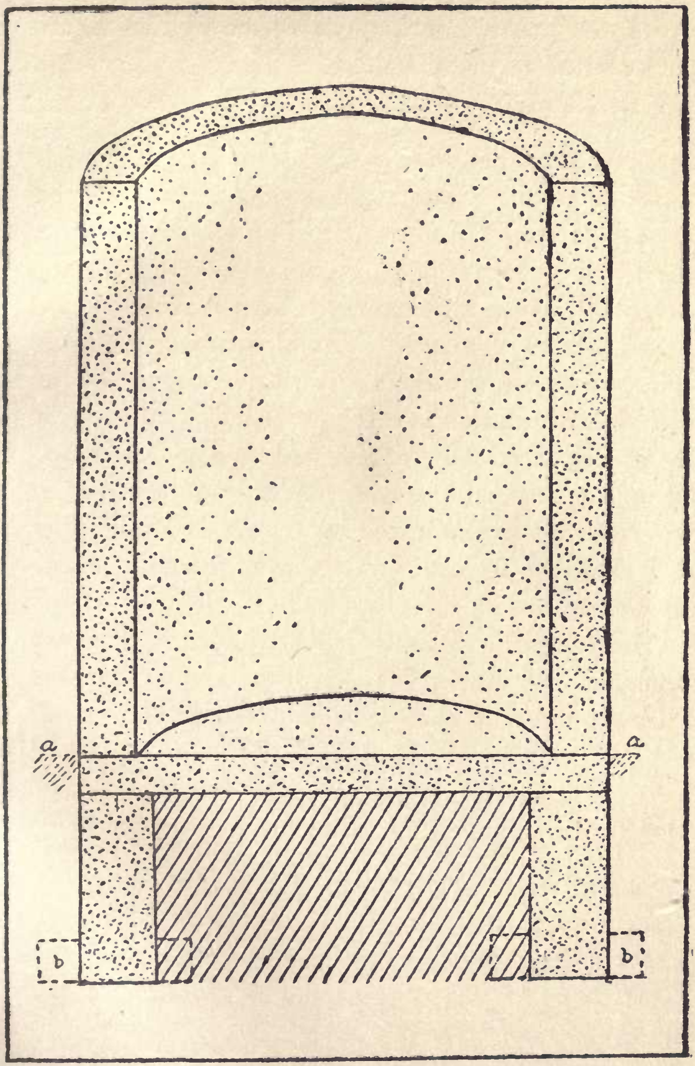

FIG. 1.—Foundation for a silo with floor at ground-level.

In the preceding table, A refers to the outside diameter of the foundation, including footing; B to the width of the footing or bearing course on the soil; C to the thickness of the footing course, and D to the thickness of the wall of foundation that rests upon footing course, and extends to ground-level.

The foundation course should be placed of concrete that is not leaner than 1:2:4 of well-graded sand and gravel or crushed stone. This is well tamped, and allowed to harden permanently before the walls of silo are erected upon same, otherwise the weight of the concrete placed upon the foundation may develop defects in the foundation that would not happen if it had ample time and opportunity to thoroughly cure before the walls were constructed above ground-level.

Where the soil is firm the excavation can be employed to furnish the mold for the outside walls of foundation, by cutting it down to the size desired; the forms for the inside wall surface can then be erected and the concrete placed.

Where the forms will permit, the floor of silo can be laid at the time the foundation is placed, and thus form a part of same; but, where the wall forms demand supporting uprights inside the silo, the floor must then be placed after the silo walls are completed.

FOUNDATION WITH FLOOR BELOW GROUND-LEVEL

At Fig. 2 is shown the usual type of silo foundation, where the floor-level is below the ground-level, which is designated by *a a* in illustration. The footing course is shown by the dotted lines *b b*, and at all times forms a part of the foundation-wall to ground-level. The best practise is to also make the footing-course a part of the floor of silo, although it cannot be done when uprights must be erected inside the forms, as previously explained; in which case the footing extends the proper distance outside and inside the foundation-wall, as shown by dotted lines, and the floor is laid inside this when the silo walls are complete. Where the silo floor is not laid with the foundation, extreme care must be employed to make the joint between edge of floor and footing water-tight, otherwise surface water will collect in the bottom of silo.

The thickness of foundation-walls, given in Table II, apply to the foundations where the floor is at ground-level as well as to those below ground-level.

FORMS FOR MONOLITHIC WALLS WITHOUT AIR-CHAMBER

After the foundation-walls have had ample time to permanently harden—so that they will bear the weight of the concrete for walls of silo—the forms for the type of wall you desire to erect are placed, with the necessary staging or uprights to carry the

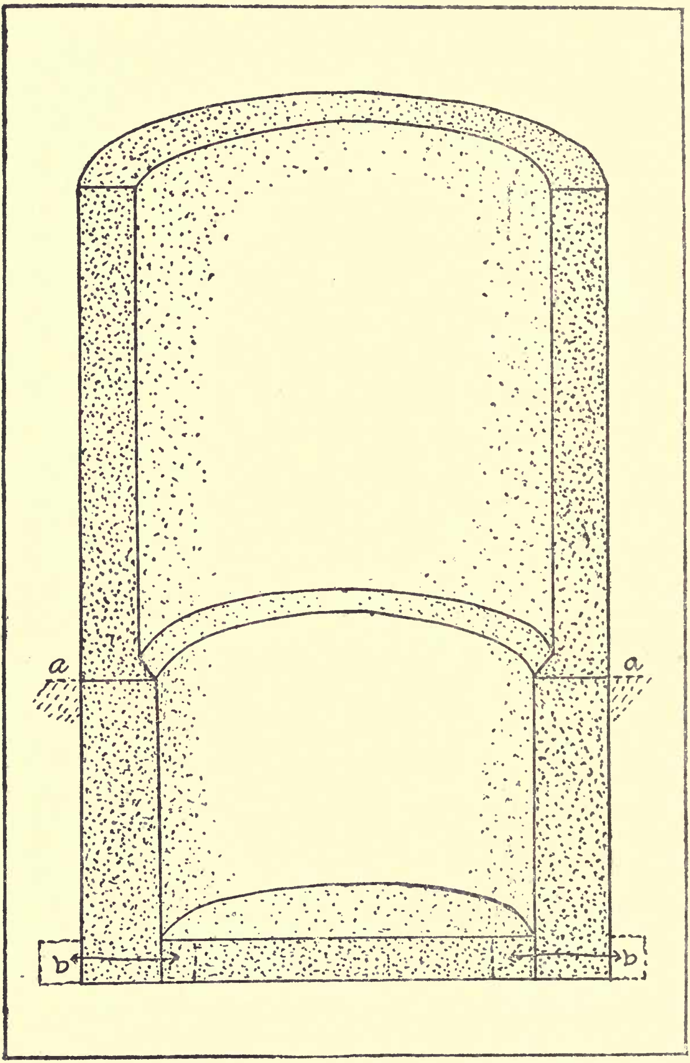

FIG. 2.—Foundation for a silo with floor below ground-level.

wall forms to the height of the silo. These uprights should be placed plumb, and securely braced or held by guy wires or ropes, so that they will serve as a guide in building the silo walls absolutely vertical.

A SIMPLE AND INEXPENSIVE SILO FORM

The most simple silo form or centering, and one that requires the least amount of lumber to erect, is shown in detail in Fig. 3. The wood clamp is built of 2x4″ strips that are at least 12″ longer than the sheet steel used for centering is wide. Thus, if the sheet steel is the usual size of 24x101″, the sides of the clamp will be 3′ in length. The upper cross-piece to clamp is cut long enough to lap onto the side-pieces and leave space for the silo wall of the desired thickness between the vertical strips. This can be made longer, and then holes bored in same so as to enable the worker to regulate the width of the wall from 6″ to 12″ in thickness, or more, as may be desired, thus making the same form adaptable to different sizes of silos.

The long strip, shown in Fig. 3, is of sufficient length to reach entirely across the diameter of the silo and then lap onto the vertical strips, to which the sheet steel is attached at each side. Thus, for a silo 10′, inside diameter, this piece would have to be 12′ long, to permit an 8″ wall to be molded. This strip is bolted to the vertical strips, as illustrated, and also bolted to the clamp upon the opposite side of the silo.

As the weight of raising the forms is largely upon these pieces, they should be at least 2x6″ and of selected wood, so that they will not bend or break from the strain.

A number of the clamps are constructed so that they will hold the sheet steel to the true circle. This requires less where the 24-gauge steel is employed than where lighter weight sheets are used.

The arrangement of the clamps and braces are shown in the plan of one-half of silo form, at Fig. 4, in which *a a* refers to the central vertical upright used to raise the silo form, as required; *b b* is the 2x6″ strip extending across the top of the silo form, by which it is raised; *c c* are the guide-strips employed to keep the silo form level when it is raised, and also when the weight of concrete is all upon one side of form; *d d* illustrates the position of the wood clamps or vertical strips attached to the horizontal 2x6″ strip, as explained for Fig. 3. The clamps designated by this letter at the quarter segment of silo form are connected to the main horizontal strip by two brace rods, *f f*, which may be made of 2x4″ lumber, bolted to the clamp and also to the sliding guides *c c* at center. The clamps *e e*, shown between the quarter segments of circle are simply employed to keep the sheet steel to the true circle. These need not be as strong construction as the clamps placed at each quarter of the circle, and are held from spreading or warping from position by

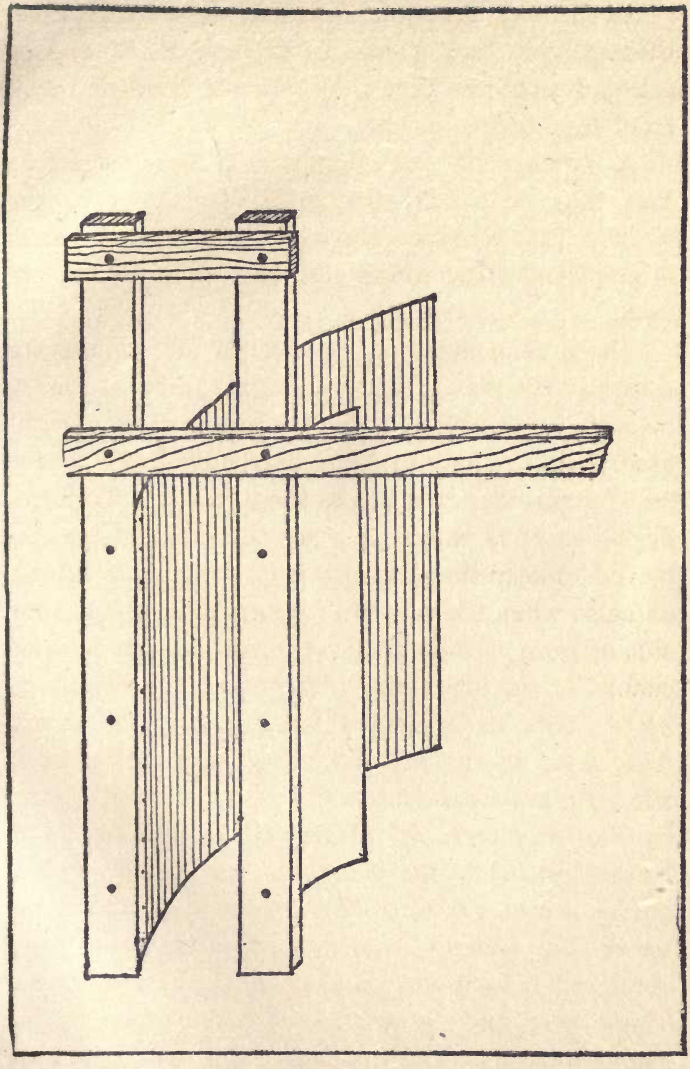

FIG. 3.—Wood clamp for molding monolithic walls.

the braces *g g*, as shown in plan. The number of these clamps must be determined by the diameter of the circle, but should never be less than two, placed between each clamp at the quarter segment of circle; nor, when the 24-gauge sheet steel is employed, should they be more than 36″ apart on the outside circumference of circle.

The strips shown at *h h* in Fig. 4, cut along one edge in a convex form, may be employed to keep the sheet steel from bending under the weight of the concrete. These are cut in the proper segment of circle so that they will fit between each clamp, around the inside circumference of your circle. Those shown at *i i* are cut in a concave form and are fastened to the outside circumference of your circle, between clamps. By using these retaining strips, or pieces of strap, iron bent into the same form and riveted to the sheet steel, the lighter weight steel may be employed. Thus, with three of these retaining strips between each clamp, No. 28-gauge sheet steel has been successfully employed for the forms or centering.

The value of employing the retaining strips and using a lighter grade of sheet steel is that the forms will thus be made lighter, as the 24-gauge sheets weigh about 17 pounds to the sheet of 24 x 101″; the 26-gauge weighs 13 pounds to the sheet, while the 27-gauge weighs 11½ pounds, and the 28-gauge weighs but 10½ pounds to the sheet. This is also able to effect a saving in the cost of the forms, as

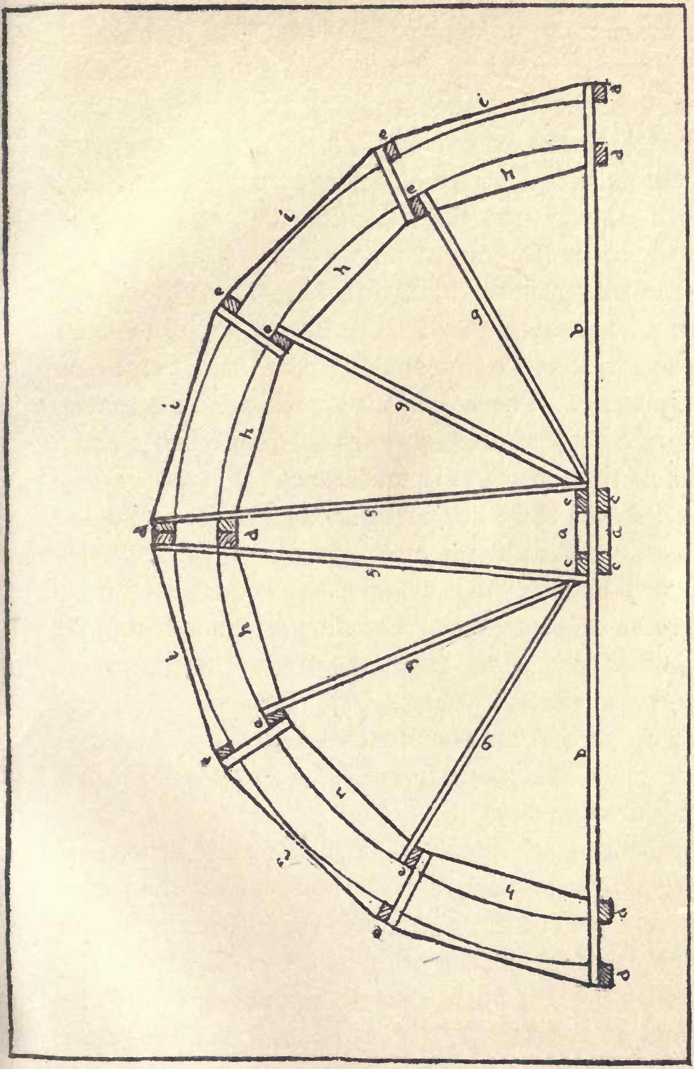

FIG. 4.—Plan for clamps and braces used with wood silo forms.

there is a difference of 20 cents a sheet between the 28-gauge and the 24-gauge.

The following table shows the number of sheets of steel required for the forms or centering for various diameters of silos, with the approximate circumference of the inside form or core, also the number of wood-clamps demanded for the forms to insure their being held rigidly in position.

TABLE III

STEEL SHEETS REQUIRED

Inside Diameter Silo.	Inside Circumference Core.	Number of Sheets for Core.	Number Sheets Outside, 6″ Wall.	Number Sheets Outside, 8″ Wall.	Number Sheets Outside, 10″ Wall.	Clamps Required for Form.
10′	31′ 4″	4	4	5	5	12
12′	37′ 6″	5	5	5	6	12
14′	44′ 0″	6	6	6	7	12
15′	47′ 1″	6	7	7	7	16
16′	50′ 2″	7	7	7	7	16
18′	56′ 6″	8	8	8	8	20
20′	62′ 8″	8	9	9	9	20

If no other means for bending the sheet steel to the required curve are at hand it may be placed over a round stick of at least 6″ in diameter, and, by fastening one end securely and exerting pressure upon the opposite end of sheet, it can be bent to conform to the desired curve. The above table shows the number of the usual sized sheets to order for both outside and inside, or core form. These are bent to the desired curve and then cut so to have the form meet exactly at the four quarters of the circle. By thus making the centering in four quar-

ter segments of a circle they are the easier taken down and assembled again. Where the diameter of silo is 18′ or 20′ the forms can be built in one-eighths, or segments equal to one-eighth of the entire circumference of circle, thus making the weight of each section less than if made in quarters. The segments or sections are bolted together, when in use, by bolts through the two clamps, that join together at the point, where each segment joins onto the next section. Thus, by placing a clamp at both ends of each section, whether quarter sections or eighths, the joining of sections is a simple matter of bolting the clamps together, making the work of assembling the forms a very easy and simple job.

The method of bolting these wood-clamps together is shown by the position of the clamps at *d d* in Fig. 4, and also by the holes in clamps shown in Fig. 3, thus making a simple and easily operated method of securing the joints. As the sheet steel can be bent slightly, the forms may be built to be adjustable to many different sizes of silos. Thus, if the forms are erected for a 10′ silo, using 4 sheets for the core form and 5 sheets for the outside form, the steel centering is attached to clamps with screws, placed through holes punched in the steel sheets. Then, to adjust to a 12′ silo, you would only have to add a portion of one steel sheet to the core and outside form and adjust the clamps around this new size of circle. This makes it easily possible to erect any diameter of silo with the one set of clamps

and steel centering by adding or removing sections to make up the desired circumference.

Where it is desired to erect an 8″ or 10″ wall for a portion of the height, finishing with a 6″ wall, two sections of the form are fitted with steel sheets to make the desired circumference. Then, when the thickness of wall is to be reduced, the clamp is slipped along the length of these sheets, allowing the surplus length of sheet to lap over onto the one that joins to same, thus reducing the circumference of circle to mold a wall of the required thickness. This leaves a mark of mold or indentation upon two sides of silo, where the sheets lap; but, as this is slight it will not be a serious defect to the work.

METHOD OF RAISING FORMS

The method of raising the forms after each course is placed is shown at Fig. 5, as well as a cross-section of wall and the molding form or centering. The vertical post shown at *a a* is made of two 2x8″ strips, placed together with a space between them of 2″, so as to permit the braces *b b* to slide between same as the silo forms are raised. The two vertical strips, *c c*, are guides that are bolted to the horizontal braces *b b*, and by pressing against the vertical posts *a a* the silo form is kept from tipping to one side; nor is it allowed to be raised higher at one side than the other. This is a most important feature, and these guides should never be left off the form, otherwise you will have

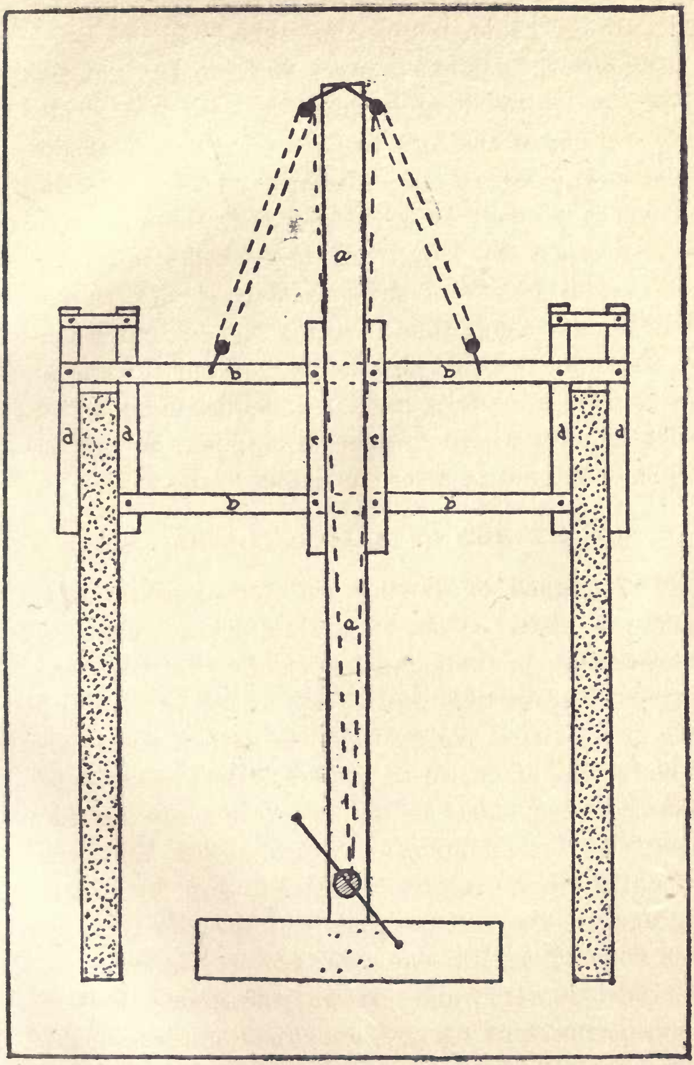

FIG. 5.—Sectional view of silo forms in operation.

no assurance that the form will not be raised higher upon one side than upon the opposite side of silo, thus throwing the wall from the vertical line or plumb. With every silo form heretofore explained, this feature has never been given attention; and its importance is apparent to any one at a glance, as it insures a perfect wall without the bother of leveling the form each time after raising. The clamps at sides are shown by *d d;* and, as the same designating letters are given to each part in Fig. 5 as in Fig. 4, it is an easy matter to understand the invaluable and important features of this simple and easily constructed silo form.

The tackle used to raise the forms is shown by the dotted lines in Fig. 5. The wire cable, or ropes, pass down upon one side of the posts, in center, to a drum or roller at the bottom of same. This drum is fitted with a ratchet-wheel and pawl, to lock the drum at any point desired, also with two arms, or cranks, for moving the drum. Hence, with two men, the form is very easily raised each time in a far more simple and desirable manner than by wire loops over levers, which do not raise the forms evenly, and consequently require greater effort, with danger of breaking out pieces of the concrete wall.

The vertical posts in center of Fig. 5 are braced at the bottom by horizontal pieces bolted to same. This is made so as to have ample bearing surface upon the ground, so the weight of forms will not cause it to sink or bury into the earth at one side, and thus

draw the wall from the vertical or plumb line. With this form of post the concrete floor may be laid in the bottom of the silo, and the uprights set upon same without injury. By keying or bracing this securely at the bottom, and staying the top of the post with guy wires, the walls of silo must be built absolutely plumb, for the forms cannot be raised in any other manner. This "fool-proof" feature will be of interest to the contractor who must intrust his work to others; and, as mistakes in this work are costly, every safeguard against errors is of great importance.

This style of form permits the placing of any reinforcement desired. The upright rods are placed with the first course of concrete, spacing them the proper distance apart. These are held in a vertical position by braces nailed to the top of the center posts until the wall has advanced enough to hold them securely. Then the braces can be removed, to finish the silo.

By nailing short strips to the center posts, horizontally, a ladder can be made for convenience in reaching the forms at every stage of the construction.

USING AUTOMATIC CLAMP

The illustration at Fig. 6 shows the use of the automatic wall-clamp, explained in CONCRETE WALL FORMS of this series, as adapted to silo work. This permits the molding of a hollow wall with a continu-

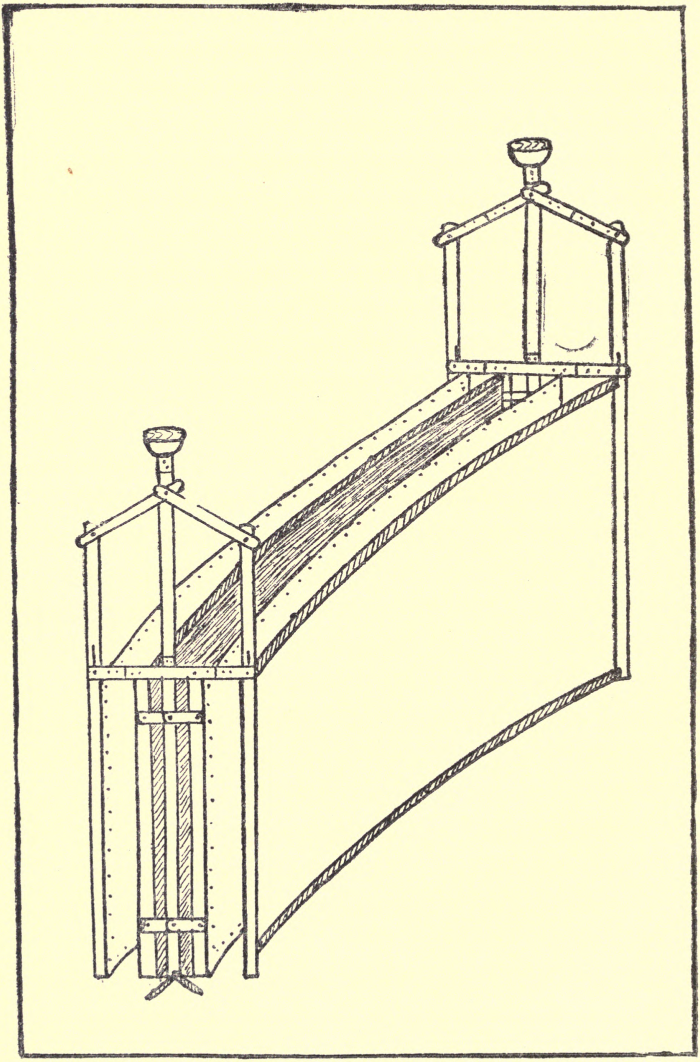

FIG. 6.—Using automatic wall-clamp, as explained in CONCRETE WALL FORMS, for silo work.

ous air-chamber between the walls, a feature that is an absolute preventative against freezing of the silage.

These wall-clamps are constructed of strap iron, and may be built by any one at a slight cost. The steel sheets are bolted or riveted to the clamps as shown in Fig. 6, and each section is then bolted together or fastened with a small clamp, if the sections are to be raised separately. The core form collapses when the center-bar with handle is raised. This same operation causes the outside forms to draw away from the concrete wall, thus freeing the form from the concrete at all points.

When the form is again lowered into position the core is pressed outward to its proper place, and the outside forms drawn in to the correct circumference. The simple act of lowering the form automatically locks it into position for filling, while the small metal bars at the bottom of the center-bar engage with the concrete wall and prevent the centering from slipping down.

The sections are reinforced with bars of strap iron riveted to the sides of the steel sheets, as shown in illustration, thus holding them to the true circumference of the circle.

The easiest method of using this style of form is not to have more than two or three clamps to each section, thus making the sections quarters or eighths of the circumference of the silo. These sections are raised separately by removing the small clips or

clamps holding the sections together. Each section can be raised and then the segments or sections again fastened together, avoiding the use of any tackle to raise the forms after each course, as two men can lift the sections from the staging erected for the workmen in placing the concrete.

By having small segments or sections the forms can be employed for many sizes of silos, by adding or removing a section as demanded, which is a valuable feature to the contractor who must build all sizes of silos.

PLASTERED SILOS

A successful type of silo construction has been recently used; and that it is exceedingly practical is shown by the illustration at Fig. 7, which illustrates the method of arranging the vertical and horizontal reinforcement and also the use of the wire lath that is attached to same.

This type of silo construction employs the placing of $\frac{3}{8}''$ vertical rods around the circumference of silo, ground plan, as per the spacing for diameter given in Table IV. To this is added the horizontal or "hoop" reinforcement, using $\frac{3}{8}''$ rods, and spacing them as instructed in Table V. These horizontal rods are tied with wire to the vertical rods at each point they intersect, thus making a skeleton or "balloon" frame of the silo.

The vertical and horizontal rods are placed so that they will be about $1\frac{1}{2}''$ from the outside of the

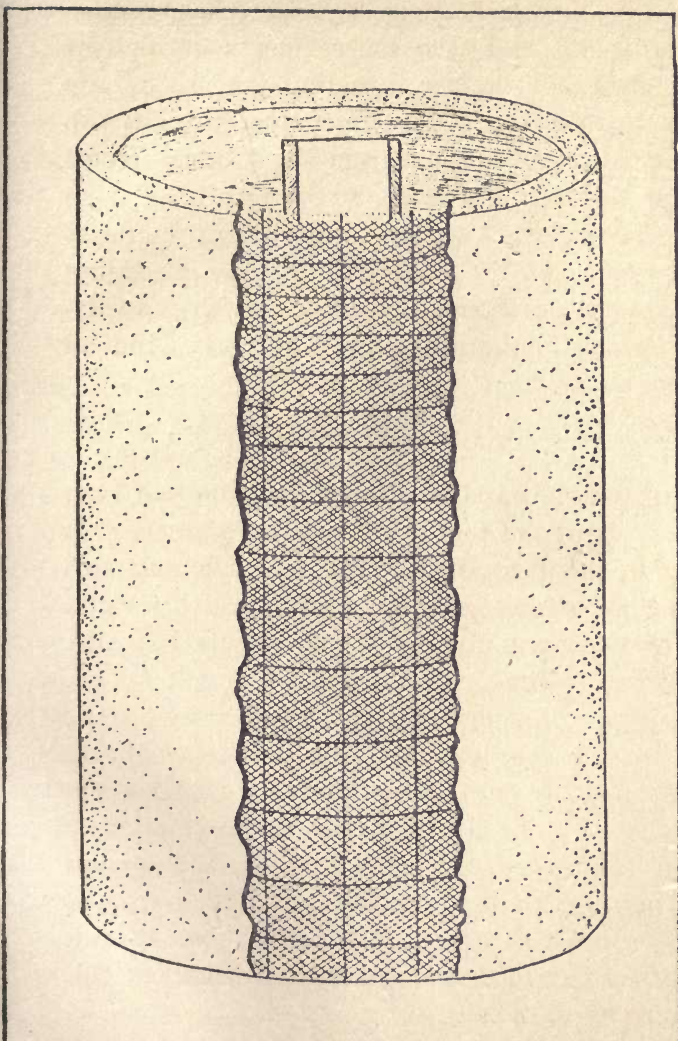

FIG. 7.—Method of constructing plastered silos.

completed wall, which is usually made about $3\frac{1}{2}''$ in thickness.

After the framework of rods are in place, sheets of wire lath, or expanded metal lath, are fastened to the rods by tying with wire at each intersection of the rods and also at the joints of the metal lath, so that the sheets are securely fastened to the framework, and thus make a reinforcement that will be ample to resist the pressure of the silage, also the strain placed upon the silo from other causes.

The concrete is then plastered upon the inside of the silo to an average thickness of 2″, and while this is damp enough to insure a good bond the plaster coat is then placed upon the outside of the metal lath. The methods followed in stucco work are of use in this system to insure a good bond between the two coats of concrete plaster applied.

The door-frames are inserted in spaces left for same as the work progresses. By having a groove on the outside of the door-frame into which the metal lath will fit, the frames are securely held in position. The roof is placed by having the $\frac{3}{8}''$ rods extend several inches above the top of silo, and these are threaded for a nut. Thus the rafters are bolted to the vertical rods that form a part of the reinforcement of the structure.

This system of construction is far in advance of the method of using a wood frame, to which wood lath are nailed and the entire surface coated with concrete plaster coats.

The plastered silo may be constructed with a continuous air-chamber by attaching the wire lath to the outside and also to the inside of the $\frac{5}{8}''$ rods. By plastering upon each side a space is left between the plaster coats that is a preventative against frost in the silo.

CONCRETE BLOCK SILOS

Silos of concrete blocks, or units, have been employed so generally that a description of this type of construction is not needful to the average concrete contractor. The manufacturers of concrete block machines put out a silo block machine for molding hollow building blocks for any diameter of silo, thus making the construction of the units the same as the manufacture of building blocks for any type of wall.

For the man who desires to make his own blocks, the type of mold shown in Fig. 8 is of value, as this molds a wet process hollow block. The molds are easily constructed by using two planks for the sides. In width these should be about 2″ more than the desired width of block (or thickness the wall is to be) at the points where the desired height of each block is measured. The planks are cut with a saw kerf for 3″ in depth. These are to receive the sheet iron dividing plates between the blocks, as illustrated. A convex form is built for the bottom of mold from wood strips, cut into the proper curve for the segment of circle the block is to take, on the inside of silo. These strips are covered with sheet iron, and

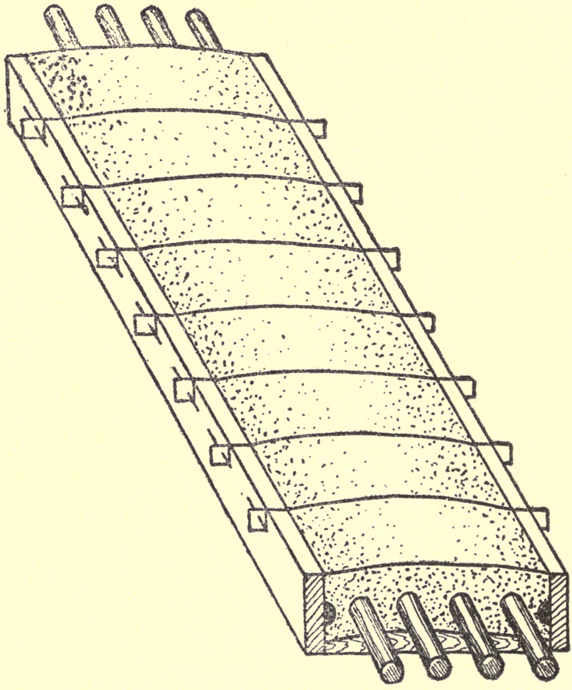

Fig. 8.—Mold for silo blocks, wet process.

the form constructed to make a bottom for the entire length of the mold.

The sheet iron dividing plates are cut in the convex and concave form shown in Fig. 9, at top. The length is equal to the length of the block, plus 4″ at each end for inserting in the saw kerf and for a hole in the ends for putting an iron pin into, to hold the side forms or planks tightly up against the "shoulder" cut upon the dividing plate.

A beveled or triangular strip of wood is now cut of the exact length of the block. This, by soaking in water, can be bent to the curve of the block, and is then nailed to the top of the dividing plate, or about 1½″ from the top, as shown in the illustration at Fig. 9. This molds a groove in the silo block for the placing of the hoops or wires used as reinforcing material. This groove is shown in the completed block at Fig. 9.

Below the triangular strip, round holes are cut for inserting lengths of gas-pipe, which mold the hollow spaces in the blocks. These pipes are well greased when the mold is assembled and also slightly flattened at one end, into which a key or crank is placed for turning the pipe around before removing same from the completed series of blocks. This is necessary, as otherwise the pipes could not be as easily drawn; but, by breaking the bond, if any, between the pipes and concrete, they are withdrawn quite easily.

Two of the dividing plates are used between each

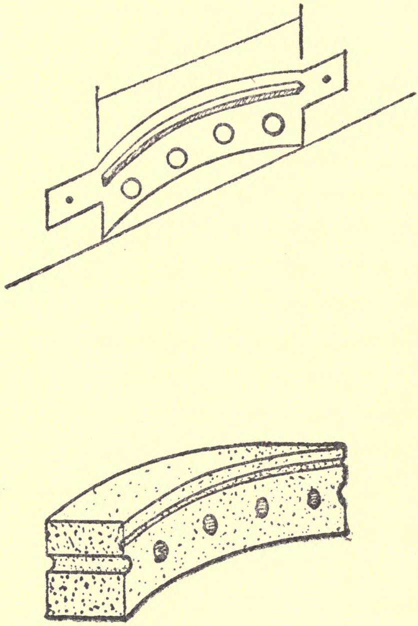

FIG. 9.—Sheet iron dividing plate and completed silo block.

block, or one dividing plate with a triangular strip upon each side, so as to mold the channel or groove for wires into both sides of block.

The form is now assembled in the manner illustrated in Fig. 8, and the concrete placed in the mold, finishing the top with the trowel, or using a template of the desired curve. The concrete is placed wet and the blocks allowed to cure in the mold, when the iron pins through dividing plates can be drawn and the side planks removed, thus releasing the entire series of blocks, which can be as many as the length of plank will accommodate.

The wood portions of this mold should be well treated to several coats of shellac or oil paint, so as to prevent the moisture in the concrete from warping the wood. The concrete is placed wet; thus a dense block is obtained with but little tamping.

The method of laying the blocks is shown in Fig. 10, also the usual manner of securing the door openings.

While not necessary, a wire hoop can be placed in each course of blocks in the groove or channel for that purpose. This will bring the reinforcement the height of the block apart. Thus, if a block 7½″ high is employed the reinforcement should be ample for any strain it will be required to withstand. This can be placed in each second course of blocks for the 5′ of distance from the top of the silo downward, if No. 5 wires are used for the wire hoops, and make the wall of ample strength.

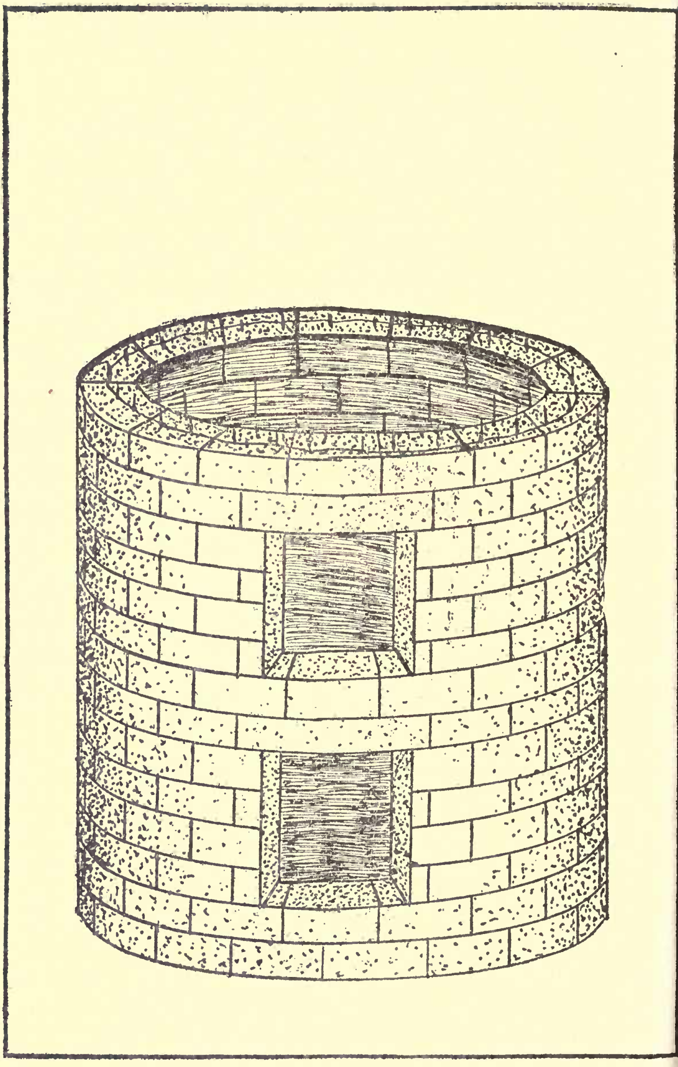

FIG. 10.—Reinforcing block silos and molding door-openings.

For the door-openings a double length block is constructed, as shown in illustration. This should be of the proper curve to conform to the circumference of circle, and also be reinforced with at least three $\frac{3}{8}''$ rods placed horizontally in same. Two of these rods are placed within about 1″ of the bottom of block, which forms the upper part of the door-frame; the third rod is placed about 3″ above this, and may be further strengthened by short stirrup rods connecting the horizontal reinforcement. The door-frames may be set in position as the blocks are placed; and, by attaching to the reinforcement of the silo, the frames are thus held rigidly in position against the pressure of the silage.

At Fig. 11 is shown a plan of laying the silo blocks so as to make a continuous door-opening from top to bottom of the silo. The blocks are molded or cut at the point they intersect at the door-opening so as to lock in the manner shown. This can be accomplished by using a block of wood set vertical in one end of the mold used for these blocks, and thus saving the labor of cutting each block to join in this manner.

The reinforcing wires are bent to form a continuous reinforcement or bond to the end of the door-opening.

In constructing the blocks for a known size or diameter of silo it is an easy matter to make them of a length so that it requires a certain number of blocks to make the exact circumference. Then, by molding a number of half blocks, the joints may be

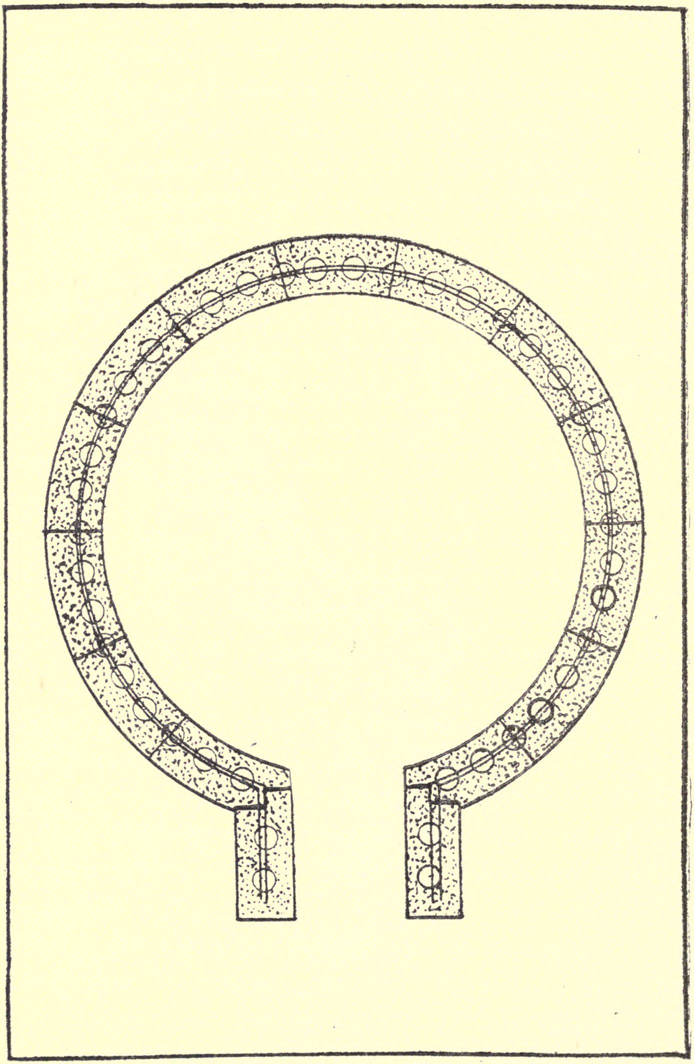

FIG. 11.—Ground plan of silo with continuous door-opening.

broken in each course laid, and the work of laying greatly simplified. This can also be arranged so as to bring the hollows or holes in blocks made by the gas-pipe exactly over those in the block below, thus permitting vertical reinforcement, if so desired.

CONCRETE FOR SILO WORK

For the manufacture of silo blocks or monolithic silo walls the usual mixture is 1:2:4, using clean, sharp sand that is well graded, and crushed stone or coarse gravel for the larger aggregate. This should not be over ½″ in diameter. The materials call for thorough mixing and enough moisture to completely wet the mix. This makes it impossible to raise the forms until the concrete placed has had time to harden or set. While this may seem a hardship to the contractor in a hurry, it is the one and only safe policy, even when a semi-dry mixture is employed. Many jobs are injured by haste in construction; for, if the concrete has not had from 24 to 36 hours to harden, even under the most favorable conditions it is a menace to the workmen employed on any job where the concrete must support the staging or scaffold. Where the forms can be filled in a few hours or one-half a day, the concrete can easily be given 24 hours to harden without delaying the work.

Where the mixture is made semi-dry it must be tamped very solidly; but in the event of a wet mixture the tamping can be replaced by placing the mixture in thin layers or courses and pressing it out

against the forms or "puddling." The wet mix will thus pack more solidly than a semi-dry mix well tamped, hardening with equal speed under favorable conditions, and giving a smoother and more perfect finish to the surface of walls.

The composition usually employed for plastered silos is the same as that used for stucco; and often a small amount of plastering hair is added to the mixture. Where lime is added to the mix the usual proportions are 2:5:1, cement, sand, and lime. Without the addition of lime the best proportion is 1:2½, using well-graded sand, although a proportion of 1:3 has been employed with success. The use of lime, either the hydrated lime as sold almost exclusively to-day or the cream of lime prepared by the plasterer as needed, is of advantage in the concrete, as it gives it great plasticity and lightens the work of spreading to a large extent.

REINFORCEMENT OF SILOS

The question of reinforcement is an important one to the silo builder; and in planning and placing the steel every precaution should be taken to prevent a weak point in the work.

At Fig. 12 is shown a type of reinforcement that employs vertical ⅜″ rods around the wall of silo, except upon each side of the door-openings, where the rods are replaced by 2″ angle irons or bars. These are connected together between each door-opening with a horizontal bar of the same material

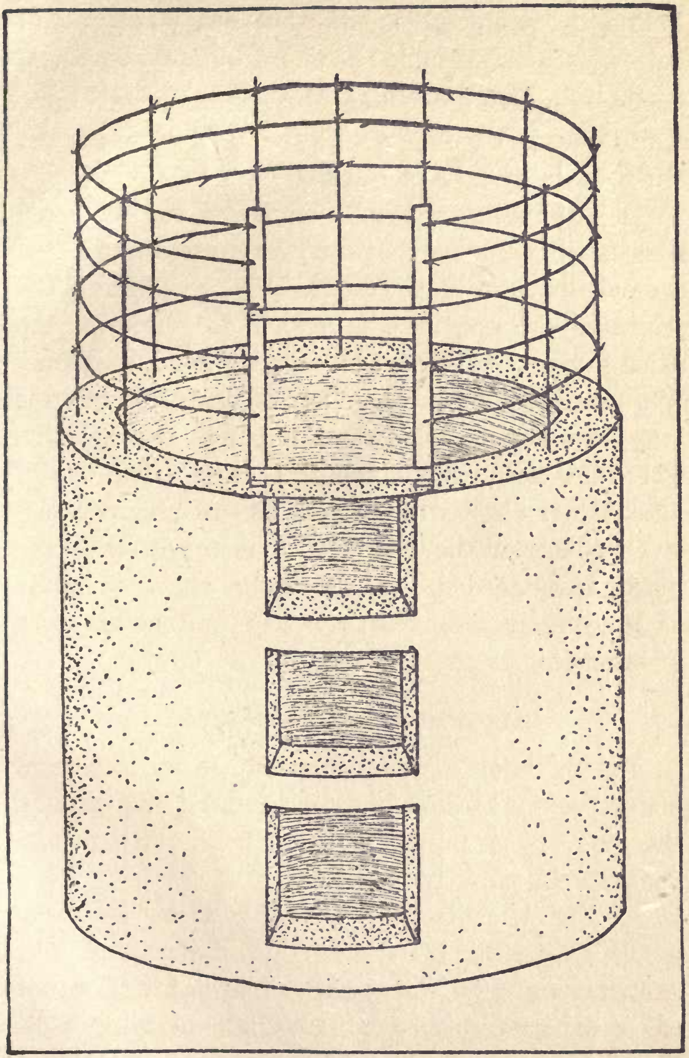

FIG. 12.—Silo reinforcement and method of placing.

bolted to the uprights. The hoops or wires extending horizontally around the silo wall are tied to the angle bars, thus forming a continuous reinforcement entirely over the wall of silo. By referring to the drawing at Fig. 12 the advantages of this type of reinforcement is easily seen; and, as it is simply constructed, there is nothing to prevent its general use.

For the vertical reinforcing rods there is nothing as satisfactory as those of $\frac{3}{8}''$ in diameter. These weigh .375 of a pound to the foot; and, when spaced around the circumference of the silo, as explained in the following table, make a reinforcement that will support its own weight and the reinforcement added to same without bending or becoming displaced, as is usually the trouble with vertical reinforcement formed of wires.

TABLE IV

VERTICAL REINFORCEMENT AND SPACING $\frac{3}{8}''$ RODS.

Height of Silo in Feet.	To 25′.		To 30′.		To 35′.		To 40′.	
	No.	Space.	No.	Space.	No.	Space.	No.	Space.
10′ to 14′ Diam.	1	30″	1	19″	2	26″	2	19″
14′ to 17′ Diam.	1	28″	1	24″	1	17″	2	27″
18′ to 20′ Diam.	....	......	....	......	1	20″	1	17″

The height of silo is given in the first line, and the number of rods to use, spaced at the proper distance apart, in the second line. Thus, in a silo 10′ in diameter and 25′ high, one $\frac{3}{8}''$ rod is used for

vertical reinforcement, each 30″ of the distance around the circumference.

The horizontal reinforcement may be rods or wires (where rods are used the most satisfactory are those ⅜″ in diameter), while No. 5 and No. 8 wire is usually employed for the horizontal hoops, as they are easier bent to the proper circle than ⅜″ rods.

TABLE V

SPACING HORIZONTAL REINFORCEMENT OR HOOPS.

Distance Measured from Top of Silo in 5′ Spaces

Diameter Silo Inside.	1-5′.	2-5′.	3-5′.	4-5′.	5-5′.	6-5′.	7-5′.	8-5′.	Size of Rods or Wires Used.
	N.-S.	N.-S.	N.-S.	N.-S.	N.-S.	N.-S.	N.-S.	N.-S.	
10′—14′......	1-18″	1-18″	1-15″	1-14″	1-11″	1-9″	1-8″	1-7″	⅜″ rods
10′—14′......	1-16″	1-11″	1- 8″	1- 6″	2- 9″	2-7″	2-6″	2-5″	No. 5 wire
10′—14′......	1-12″	1- 7″	2- 9″	3- 9″	3- 8″	3-7″	3-6″	3-5″	No. 8 wire
14′—17′......	1-18″	1-18″	1-14″	1-11″	1- 9″	1-7″	1-6″	1-5″	⅜″ rods
14′—17′......	1-12″	1- 9″	1- 6″	2- 8″	2- 7″	2-5″	3-7″	3-6″	No. 5 wire
14′—17′......	1-11″	1- 5″	2- 7″	3- 8″	3- 6″	3-5″	3-5″	3-4″	No. 8 wire
18′—20′......	1-18″	1-18″	1-12″	1- 9″	1- 7″	1-6″	1-5″	1-4″	⅜″ rods
18′—20′......	1-12″	1- 7″	2- 9″	2- 7″	3- 8″	3-7″	3-6″	3-5″	No. 5 wire
18′—20′......	1- 9″	2- 9″	3- 9″	3- 6″	3- 5″	3-4″	3-3″	3-3″	No. 8 wire

The distance from the top is measured in spaces of 5′. Thus, in the first line, 1–5′ refers to the first 5 feet from top of silo downward; 2–5′ is the second 5′; 3–5′ is the third 5′; or 15′ from top of silo, and in this manner to the distance to 8–5′, or 40 feet, measured downward from top of silo. The greatest pressure is at the bottom of silo, the silage ex-

erting a side pressure of about 11 pounds to each square foot, for every foot of depth.

In the next line N. refers to the number of rods or strands of wire used for each hoop or horizontal reinforcement. S. refers to the distance in inches these hoops or horizontal reinforcements are spaced apart. The first column states the inside diameter of the silo, while the last column states the size of the wire or rods used.

Thus, for a silo 10′ to 14′ in diameter we would use 1, $\frac{3}{8}$″ rod, spaced 18″ apart for the first 5′ from the top, also for the next 5′ to 10′; 15″ apart for 10′ to 15′, 14″ apart for 15′ to 20′, 11″ apart for 20′ to 25′, 9″ apart for 25′ to 30′, 8″ apart for 30′ to 35′, and 7″ apart for 35′ to 40′, thus bringing the greatest strength of the reinforcement at the bottom of the silo, where the greatest pressure is exerted by the column of silage.

The hoops or horizontal reinforcement should be tied to the vertical rods with wire. These may be added as the forms are filled and raised, so they will not interfere with the clamps used on the forms.

The system of reinforcing given is ample for a wall of 6″ in thickness or greater when made monolithic, or it may be applied to plastered silos where the wire lath or expanded metal lath is securely tied to the reinforcing wires and rods.

DOORS FOR THE SILO

The usual size of silo door is 24 x 30″, and in some types of construction the height has been increased to 36″. The door should be amply large so as to permit the easy removal of the silage, yet if made too large there will be a weak point in the wall by the excessively large opening. For a door 24 x 30″ they should be spaced 5′ 6″ apart, center to center, on the wall of silo, beginning at a point about 3′ from the bottom on a silo with floor at ground-level and about 18″ above ground-level, on a silo where the floor is below ground-level.

At Fig. 13 is shown two types of silo doors. That at *a* has a channel or groove molded upon the inside of the silo wall, into which one side of the silo door fits tightly. The door is built of an outer and inner sheathing of tongued and grooved lumber, nailed to 4 or 6 cleats of 2 x 4″ lumber, which are in length equal to the width of the door. The door shown at *a* fits tightly into the opening; and, with strips of tar paper inserted around between door and frame, the joint is made air-tight.

The type of door shown at *b* (Fig. 13) is made of the tongued and grooved lumber nailed to the 2 x 4″ cleats upon each side. This door is beveled upon all four sides; and when drawn tight with the bolt and cross-bar, with strips of tar paper around same, the joint cannot but be air-tight. Care should be used to make the doors so that they fit perfectly, as other-

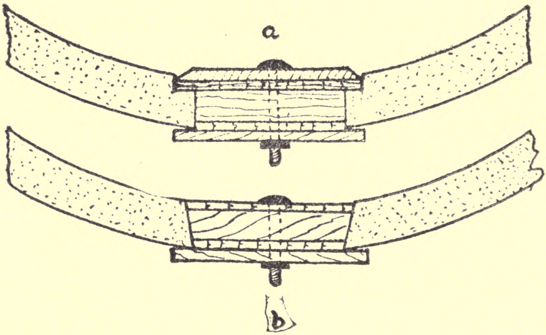

FIG. 13.—Sectional view of two styles of silo doors.

wise the silo cannot be absolutely air-tight; and unless so the results will not give satisfaction.

The view of door shown in Fig. 14 illustrates the cross-bar or 2x4″ strip, which is cut 3′ long and bolted to the center of door. This strip rests against the walls of silo on each side of the door-opening. Thus, by tightening the nut on the bolt, the door is drawn closely into the frame or opening for same.

The dotted lines in Fig. 14 show how the reinforcement should be placed at the point where each door-opening will come in the silo wall. Two $\frac{3}{8}$″ rods are used upon each side of the opening, and these are placed so that they are within $1\frac{1}{2}$″ of the surface of concrete around the door-frame. The pressure exerted against the silo wall at this point, by drawing the doors into position, makes this precaution of ample reinforcing an important one for the builder who desires durability in construction, even in monolithic silos with heavy walls. This reinforcement is necessary where plastered silos are constructed, as the thickness of wall is not enough to withstand the pressure exerted by drawing the doors into position with the bolt, unless strongly reinforced.

A continuous door for the silo is shown in the illustration at Fig. 15. The forms are built to mold this opening of the desired width, which is usually the same upon the inside as the width of the silo door. The thickness of these wing walls is best made the same as the walls of silo, which will avoid

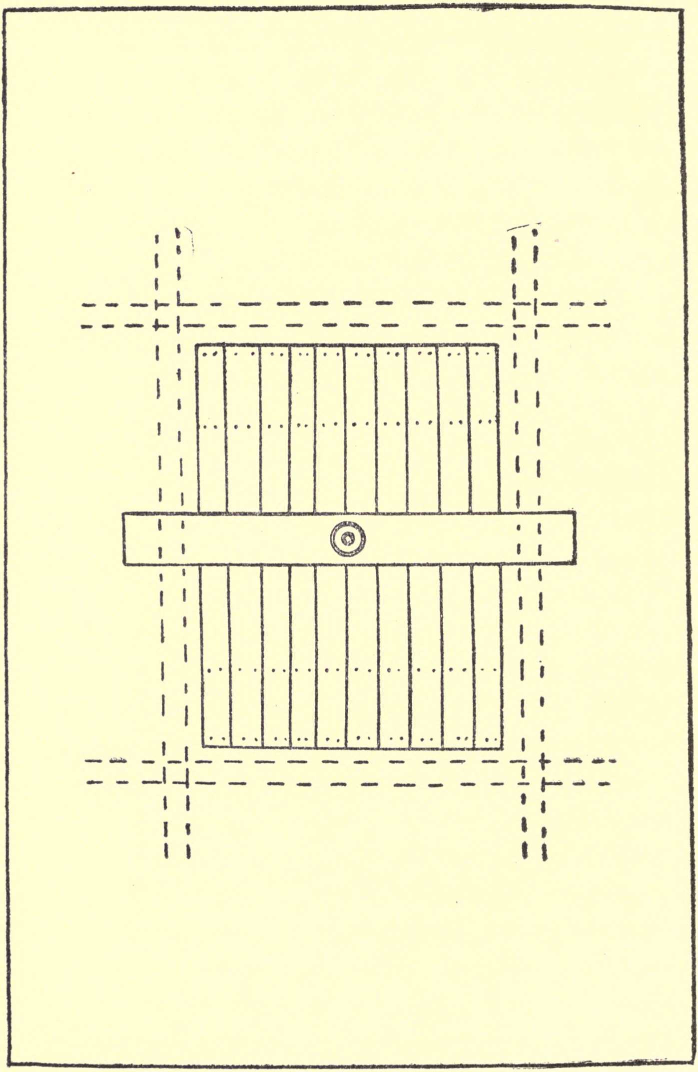

FIG. 14.—Silo door and reinforcement for opening.

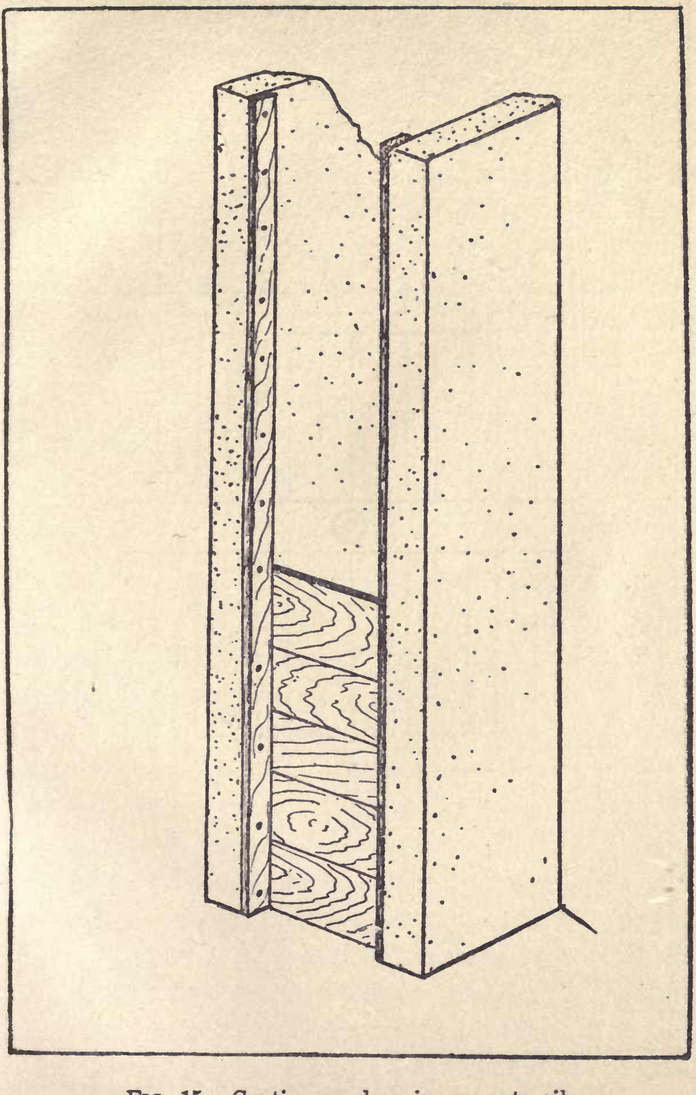

FIG. 15.—Continuous door in concrete silo.

having a separate form to mold same. The opening is closed by using short lengths of tongued and grooved planks, supplemented with a thickness of tar paper behind same. Two thicknesses of these planks are employed, one at the outside opening of the door, with the other at the opening upon the inside of silo. The latter depends upon the pressure of silage to hold them in place and are placed as the silo is filled.

The outside planks are held in place by 2x4″ strips bolted to the concrete walls, the bolts for same being imbedded in the concrete as the material is placed in form.

SILO ROOFS

A successful type of silo roof, using concrete as the covering material, is shown at Fig. 16. The rafters are cut to give the pitch desired, and the roof framed so that a dormer-window or opening is placed upon the side of silo from which it will be filled. The rafters are securely fastened to the wall by bolts imbedded into the concrete of the last course. The $\frac{3}{8}$″ rods used as vertical reinforcement can also be permitted to extend above the last course of concrete and then fitted with threads and a nut so as to bolt the rafter at the foot, cut securely to the wall of silo. The space between rafters is now filled with concrete, flush to the top edge of rafters, and over the top of rafters wire lath, or expanded metal lath, is nailed. This is treated to a plaster coat of con-

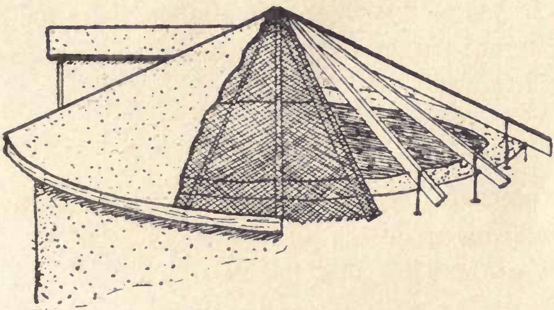

FIG. 16.—Details of constructing concrete silo roof.

crete, pressing it well against the lath to press through and form a secure key. This should not be less than $1\frac{1}{2}''$ in thickness, and is best at about $2''$ or $2\frac{1}{2}''$. The rafters must be spaced close enough so that the metal lath will not sink or bend under the weight of the concrete placed, or they may be reinforced by heavy wires stapled to the rafters every $6''$ apart around the roof for the first $3'$ from the eaves upward.

Before the plaster coating is applied, a thin wood strip may be nailed to the butt ends of the rafters as a fascia or finishing strip to the roof. This must be thin, so as to bend easily to the circle. In placing the concrete plaster, this strip will be of value in getting the eaves or edge of the roof even and symmetrical. The concrete for the roof will give the best satisfaction when made in the proportions of 1:3, using sharp, well-graded sand.

ORNAMENTAL ROOF OR WALL FOR SILO

At Fig. 17 is shown an ornamental wall for the silo that extends above the top of the roof. This is in the form of a parapet, with embrasures and merlons molded to suit the wishes of the builder. The diameter of the parapet is 4 inches more than the diameter of the silo. This requires a $2''$ strip to be placed at the bottom of mold for parapet, as shown in illustration (Fig. 18). The inside mold for this part of the wall is $4''$ more in diameter than the silo, thus molding a $2''$ ledge entirely around the

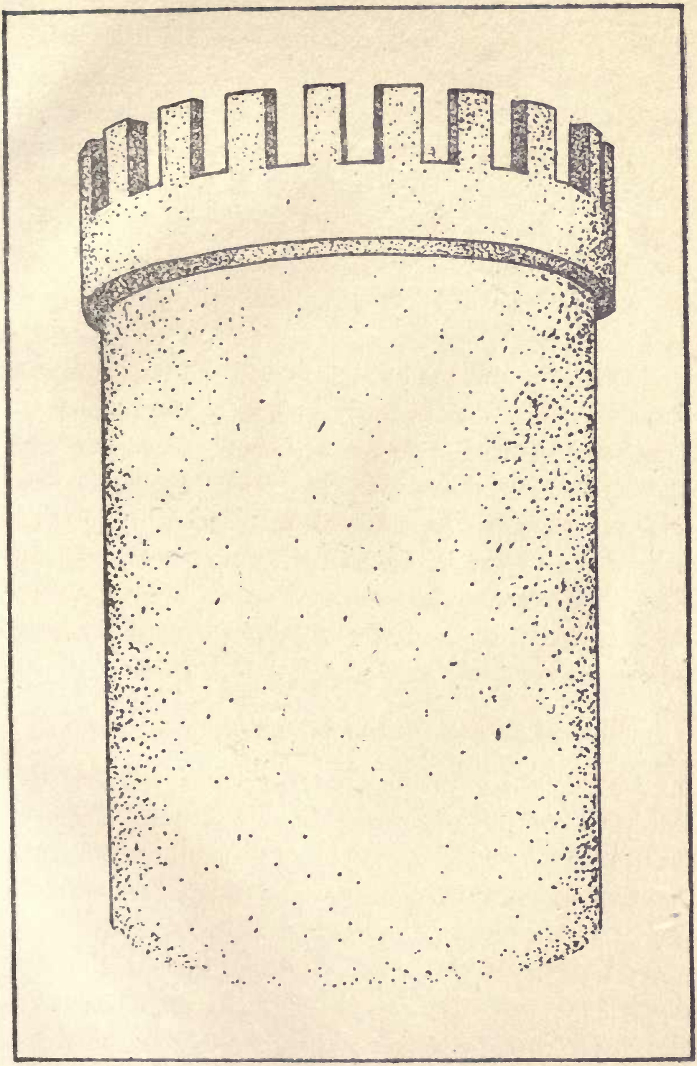

FIG. 17.—Ornamental roof for concrete silo.

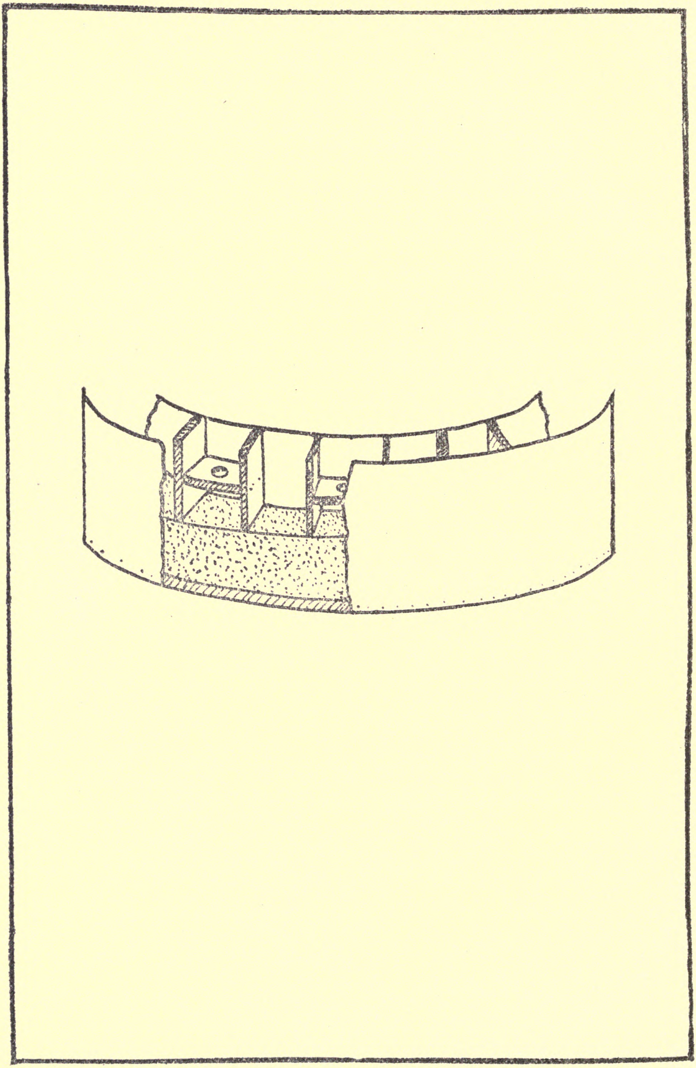

FIG. 18.—Details of constructing ornamental roof to silo.

inside of the silo for the placing of rafters for the roof. This ledge is placed so that it will be even with the embrasures entirely around the parapet, thus enabling the water to be easily carried off from the roof.

The concrete is filled into mold up to the point where the ledge is placed, then the wood forms for embrasures are set inside the mold at the desired distances apart, and the concrete tamped around same to the top. These wood forms are constructed of three short boards, with the center one, or cross-piece, bored to supply a hold for removing the form from the concrete. The construction of forms is shown at Fig. 18, with the method of placing and filling the form with the concrete.

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